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Synthesis

Dynamics of pastoral traditional ecological knowledge: a global state-of-the-art review

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ABSTRACT. Traditional ecological knowledge enables pastoralists to cope with social-ecological changes, thereby increasing the sustainability of their practices and fostering social-ecological resilience. Yet, there is a significant knowledge gap concerning the extent to which pastoral traditional ecological knowledge has changed over time at the global level. We aim to fill this gap through a systematic literature review of 288 scientific studies on pastoral traditional ecological knowledge. We reviewed 152 papers in detail (selected randomly from the 288) for their content, and focused specifically on 61 papers that explicitly mentioned one of the four types of knowledge transition (i.e., retention, erosion, adaptation, or hybridization). Studies on pastoral traditional knowledge represent less than 3% of all the scholarly literature on traditional ecological knowledge. Geographical distribution of the 288 case studies was largely biased. Knowledge domains of pastoral knowledge such as herd and livestock management, forage and medicinal plants, and landscape and wildlife were relatively equally covered; however, climate-related knowledge was less often studied. Of the 63 papers that explicitly mentioned transition of pastoral traditional ecological knowledge, 52 reported erosion, and only 11 studies documented explicitly knowledge retention, adaptation, or hybridization of traditional knowledge. Thus, adaptation and hybridization was understudied, although some case studies showed that adaptation and hybridization of knowledge can efficiently help pastoralists navigate among social-ecological changes. Based on the review, we found 13 drivers which were mentioned as the main reasons for knowledge transition among which social-cultural changes, formal schooling, abandonment of pastoral activities, and transition to a market economy were most often reported. We conclude that future research should focus more on the diverse dynamics of pastoral traditional knowledge, be more careful in distinguishing the four knowledge transition types, and analyze how changes in knowledge impact change in pastoral practices and lifestyles. Understanding these phenomena could help pastoralists' adaptations and support their stewardship of their rangeland ecosystems and biocultural diversity.

Key Words: *Indigenous knowledge; pastoralism; rangelands; social-ecological systems; transition; transmission*

INTRODUCTION

Since the 1992 Rio Earth Summit, the importance of traditional ecological knowledge (TEK) in the conservation of biological and cultural diversity has been increasingly acknowledged by both the scientific community and policy-makers around the globe (Maxted et al. 2002). TEK plays a vital role in the livelihoods of rural communities and the sustainable management and use of natural resources by Indigenous peoples and local communities (Olsson and Folke 2001). Opinions about TEK, previously rife with negative characteristics such as being static and archaic, are now appreciating the dynamic nature of this knowledge and related practices. An increasing number of studies involving traditional farmers (Cristancho and Vining 2009, McCarter and Gavin 2014) and hunter-gatherers (Fernández-Llamazares et al. 2015, Gallois et al. 2015) have shown nonadaptive changes in TEK, mostly loss of TEK due to changes in intergenerational transmission mechanisms or other drivers (Srithi et al. 2009, Reyes-García et al. 2013). But despite a myriad of cultural pressures, many aspects of TEK systems are resilient. There is mounting evidence that TEK is adaptive to changes in the environment and is fluid with social-economic and cultural changes (Berkes et al. 2000, McCarter et al. 2014). Thus, not all changes in Indigenous and local knowledge systems should be labeled as knowledge loss as long as loss of knowledge is not accidental and does not impair the efficient functioning of the practice. Thus, changes should often be evaluated from an adaptation perspective (Jandreau and Berkes 2016).

Dynamic adaptation of knowledge requires transmission between and within generations; otherwise, erosion or maladaptation of TEK is inexorable (Cavalli-Sforza et al. 1982, Turner et al. 2000). Changes or transitions in TEK, thus, can arise from changes in knowledge transmission processes and mechanisms but also from changes in the social, economic, and environmental systems that also affect knowledge needs; i.e., what knowledge is regarded as relevant and adaptive (Salpeteur et al. 2016). If the flora of a place becomes decimated, the community will know fewer flora elements than previous generations but will retain what becomes relevant (Duenn et al. 2017); in a system where technology is adopted and natural conditions manipulated, less awareness or knowledge about climate signs is adaptive too (Nkuba et al. 2019). Yet in a system where rapid changes affect social structures, and the needed knowledge for practicing the livelihood becomes impaired by lack of knowledge transmission, knowledge loss becomes nonadaptive (Srithi et al. 2009).

While TEK and TEK changes for Indigenous peoples and local communities are increasingly the subject of studies, the status of and trends in TEK for pastoral Indigenous peoples and local

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communities seems to have received less attention than that of other groups, while the relevance of pastoralism globally remains undeniable (Johnsen et al. 2019). These knowledge gaps and the urgency of their study are highlighted through the planned 2026 International Year of Rangelands and Pastoralists declared by the United Nations, which has announced the intention to address Indigenous knowledge and culture of pastoral communities (Kelly 2020). Globally, pastoralists are reported to number from 250 to 500 million people (McGahey et al. 2014, Johnsen et al. 2019). Relying on their TEK, pastoralists across the globe have been able to produce livestock in often unpredictable and highly variable conditions of rangelands that range from deserts to steppes, tundras, savannah, and mountainous areas (Stolton et al. 2019). This lifestyle is the result of close and intimate interrelations between people and nature, which lead to the formation of rich and complex bodies of knowledge, practice, and beliefs (Farooquee and Nautiyal 1999, Fernández-Giménez 2000, Molnár 2017). Many pastoralists are encountering rapid and fundamental changes in climate, the frequency of droughts and floods, the market economy, forage and fodder availability, social-cultural systems, and land use rights, but importantly, also regulations and policies that limit some of their practices and affect processes needed for the generation and transmission of TEK (Galvin 2009, Reid et al. 2014, Herrero et al. 2016, Belayneh and Tessema 2017). Such changes are leading to notable transitions in pastoral TEK (Bussmann et al. 2018, Hedges et al. 2020).

Pastoral TEK is not only essential for its role in improving the functionality of rangeland ecosystems (Shen et al. 2019), biological diversity (e.g., productive local livestock breeds that are tolerant of unique environments) (Hoffmann et al. 2014), sustainable management (conservation values of territories and their flora and fauna) (Fynn et al. 2016), and social and cultural preservation (e.g., 22 intangible cultural heritage items on the UNESCO list) (Stolton et al. 2019), but also for enhancing the social-ecological resilience and adaptability of pastoral communities to the challenges caused by diverse global changes (Oteros-Rozas et al. 2013, Yacoub 2018). Pastoral TEK contains several domains such as herd management; forage, fodder, and medicinal values of plant species; weather forecasting; and management of spatiotemporal heterogeneity of natural resources. Hence, lack of knowledge transmission or any negative change in different knowledge domains of pastoral TEK can cause irreversible effects on pastoral systems and their sustainability (Jandreau and Berkes 2016). Pastoral knowledge and practices are context-based and locally grounded, evolving and adapting to specific social-ecological conditions. However, this knowledge is regionally manifested and globally relevant (Brondízio et al. 2021), and has elements in common across pastoral systems. A recently published Scientists' Warning to Humanity on threats to Indigenous and local knowledge systems raises the importance of globally assessing the status of and trends in TEK systems (Fernández-Llamazares et al. 2021), and highlights how common global patterns are similarly affecting locally adapted knowledge systems. Such assessments are largely missing in the context of pastoralism, and few efforts have cut across disciplinary topics or regions (see Manzano-Baena et al. 2021 for a discussion).

We aim to synthesize the state of the art of knowledge on pastoral TEK and its dynamics, cutting across disciplinary topics and regions. To do so, we conducted a systematic review of scientific papers that dealt specifically with changes in pastoral TEK. To understand whether reported changes are viewed as adaptive, we focused on four types of TEK transition: retention, erosion, adaptation, and hybridization (see *Theoretical Background* for definitions). We addressed whether research is homogenous across knowledge domains (e.g., general ecological knowledge, knowledge on livestock management), and across main pastoral mobility types (sedentarism, transhumance, and nomadism) in search of regional or global patterns that could indicate drivers of change and threats to adaptive TEK dynamics.

THEORETICAL BACKGROUND

Prior to providing a definition for TEK, we defined Indigenous peoples and local communities as typically, ethnic groups who are descended from and identify with the original inhabitants of a given region who are dependent on nature for providing necessities of their livelihood in a sustainable way (IPBES 2019). TEK systems are cumulative bodies of knowledge, practices, and beliefs of Indigenous peoples and local communities that evolve by adaptive processes and are handed down through generations by cultural transmission (Berkes et al. 2000). We note that this definition is largely consistent with the one of "Indigenous and local knowledge systems" used by IPBES (2021), which defines these systems as "social and ecological knowledge, practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environment".

While pastoralism has multiple definitions and understandings, we focus on pastoral livelihoods that aim at raising domesticated and semidomesticated livestock within nature. This entails the movement of people and herds across landscapes, making use of natural vegetation and crop by-products. Pastoralism is about animals walking to their feed instead of having it grown, cut, and brought to them. In pastoral systems, animals are grazed and foraged in an extensive system instead of being stall-fed in an intensive system (Köhler-Rollefson 2020).

Four knowledge transitions were considered in this study. Retention is defined as the continuity and persistence of TEK without significant change in its quality and quantity; erosion is the decline or loss of TEK; adaptation is the transformation of TEK to adjust to changes in the environment and conditions; and hybridization is the integration of TEK into another knowledge system (Thomas and Twyman 2004, Zent 2013, Fernández-Llamazares et al. 2021). While much research has focused largely on loss of pastoral knowledge (e.g., Hedges et al. 2020), many pastoral knowledge systems have also demonstrated resilience to social-ecological changes due to their inherently adaptive and dynamic nature (Galvin 2009). The adaptability and resilience of pastoral knowledge systems is evident in many ecosystems around the world, which bear evidence of pastoral practices over millennia (Jandreau and Berkes 2016, Ellis et al. 2021).

We acknowledge that changes in TEK ramify through complex pathways, and that causality flows in multiple directions and is often circular. TEK changes usually modify the ecosystems that are shaped by such systems, and then the opportunities for practicing TEK (as a local expression of culture) are constrained

Table 1. Variables elicited and used for the review (TEK: traditional ecological knowledge).

Variable	Description	Number of papers
Year	Publication year	152
Country	Place of the study	288
Pastoral system type	Nomadism (nomad and semi-nomad); Transhumance (transhumant and semi-transhumant); Sedentarism (sedentary)	152
Knowledge domain	Herd/Livestock (subdomains: a. herd management; b. animal husbandry, veterinary); Forage/Medicine (subdomains: a. Forage and fodder species; b. medicinal species); Landscape/Wildlife, etc. (subdomains: a. landscape and ecology; b. wildlife; c. general biology); Climate (subdomain: a. weather and climate); Social-cultural (subdomains: a. social, economic, and political aspects; b. culture and beliefs)	152
TEK transition	Yes (TEK transition was mentioned); No (TEK transition was not mentioned)	152
Type of knowledge transition	Erosion (reduction of the knowledge was reported); Retention (no change was reported, and continuity was the state of knowledge transition); Hybrid/integration (TEK integrated into another knowledge system; i.e., scientific knowledge); Adaptation (new knowledge for adaptation exposed to environmental, climatic, political, cultural, and economic changes); No report (there was no report that mentioned any transition)	152
Robustness of reported transition	Evidence-based (transition was evaluated based on an analysis of data gathered from a sample); Anecdotal (transition was mentioned only in some pastoralists' quotes and was not based on analyzed results); Non-evidence based (not based on data analysis or pastoralists' quotes, but simply mentioned by the authors).	63
Drivers of knowledge transition	Causes of change in pastoral TEK. Drivers were identified based on direct sentences in the Results and Discussion sections of the reviewed paper. Drivers were not predetermined, and they were added when a new driver was identified in the paper.	63

by the new ecological trajectories (Lyver et al. 2019). As a result, the change itself, the cause of the change, and the consequences of that change are often linked and iterative (see Holling and Gunderson 2002). In short, pulling apart one thread in the cultural fabric of a given TEK system can lead to the unraveling of the social and ecological fabrics that have sustained pastoralists for centuries and millennia (Ford et al. 2020).

We also note from the outset that none of the authors are members of pastoralist communities, and that our review reflects a situated and partial interpretation of pastoral knowledge dynamics. However, we draw on several decades of in-depth field-based ethnographic experience among pastoral societies on several continents. While we see value in bringing into focus the global extent of pastoral TEK, we understand that a global review such as this one has the potential to obscure the very place-based nature of TEK and the rich diversity of pastoral cultures and knowledge systems (see Ford et al. 2016). By presenting real-world examples from all inhabited continents, we aim to emphasize the different place- and culture-specific ways in which pastoralists navigate changes in their knowledge systems

METHODS

The first step of the review process was to undertake a systematic literature search for peer-reviewed scientific articles about pastoral TEK using Web of Science. This search was carried out on 28 November 2019 and was guided by keywords that covered various phrases for both TEK and pastoralists which were selected and applied to find all available papers published in English regarding pastoral TEK. We used the following Boolean phrase to search not only the titles, but also the whole body of the papers:

TS = (("aborigin* knowledge" OR "traditional knowledge" OR "traditional local knowledge" OR "ecological knowledge" OR "traditional environmental knowledge" OR "Indigenous knowledge" OR "local knowledge" OR "folk knowledge") AND (pastoral* OR flock* OR herd* OR shepherd*)).

This led to the identification of 382 papers, from which 372 papers were traceable (Appendix 2). In the next step of the study, the title, Abstract, and Materials and Methods sections of all 372 papers were screened to omit papers unrelated to pastoral TEK. Thereby, 84 papers were eliminated in this phase. For instance, using keywords "flock" or "herd" with TEK-related keywords such as "local knowledge" led to some fishing-related TEK papers, which were disregarded at this phase. For the remaining 288 papers, we reviewed the types of TEK transition reported (especially adaptation and hybridization), and the countries where each study was conducted (Table A1.1).

In the third step, we proceeded to subsample papers for a more detailed, quantitative review. To do so, the 288 papers were sequentially numbered (1 to 288), and a random number generator was applied (using the "= RAND ()" function in Microsoft Excel 2019) to select the first approximately 102 papers, with a further addition of 50 more papers to assess the robustness of findings (Table A1.2). For these papers, we recorded the title, journal, DOI, and first author's name, and eight variables of interest: year of the study, the country where the study was conducted, pastoral system type, studied knowledge domain, mention of TEK transition, type of knowledge transition, robustness of reported transition, and drivers of knowledge transition (Table 1). Classification of papers as reporting knowledge transitions (and transition type) was done based on text mentions (in the Results and Discussion), not on our own interpretation of the paper's data. To check the robustness of reported transition type, three different states of evidence-based report of transition, anecdotal report of transition, and non-evidence-based report of transition were considered. Further explanation is provided in Table 1. Since the relative frequency of the investigated variables was not significantly different between the primary studies (102) and the final set (152) ($p > 0.05$; Table A1.3), the result was viewed as robust enough, so the remaining (136) papers were not inspected for this detailed quantitative analysis.

We conducted an additional bibliographic search to compare the research attention given to TEK pastoralist studies in relation to all studies of TEK. We compared the outcomes of the pastoralism-related Boolean phrase to the outcomes of the following search query:

TS = ("aborigin* knowledge" OR "traditional knowledge" OR "traditional local knowledge" OR "ecological knowledge" OR "traditional environmental knowledge" OR "Indigenous knowledge" OR "local knowledge" OR "folk knowledge").

Statistical analyses

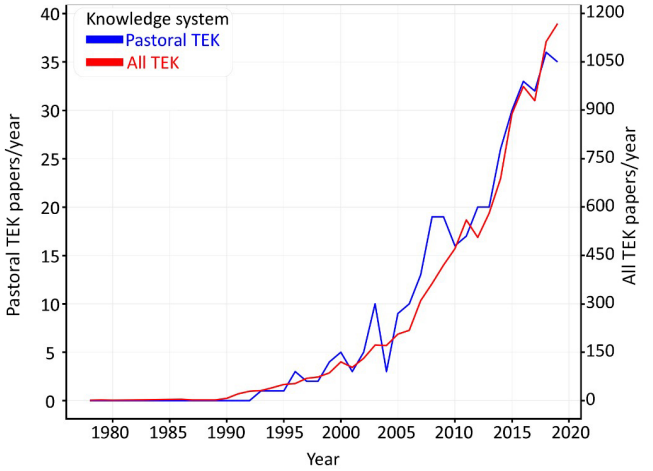
All analyses were conducted in R using Rstudio software [Version 1.2.5033]. Descriptive analysis and visualization were performed using ggplot2 and dplyr packages. The Wilcoxon rank sum test was used to assess the statistical significance of two-level variables (e.g., comparing the primary and final database), and the Kruskal-Wallis test was used for observed variables with more than two levels (i.e., pastoral system type) at a 95% confidence interval. Additionally, a global map of the frequency of studies published was produced using the rworldmap package. The final database with 19 columns and 152 rows and R scripts is appended as a supplementary file, including meta-data (Tables A1.1, A1.2, A1.3; CodeA1.1).

RESULTS AND DISCUSSION

Pastoral traditional ecological knowledge studies are few and geographically biased

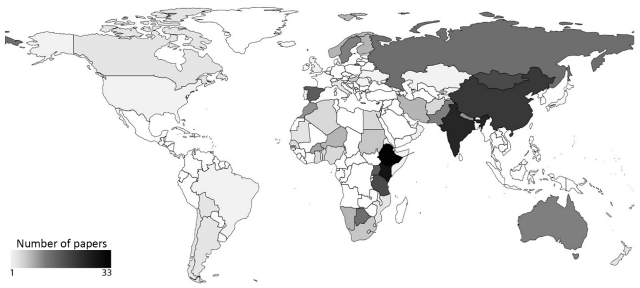
The number of scientific studies on TEK in general showed an increasing trend over the last four decades, with a parallel trend for studies on pastoral TEK. Additionally, all studies reported that pastoralists carry valuable and deep knowledge regarding different aspects of their pastoral social-ecological systems. However, the proportion of TEK studies that focused on pastoral TEK was low: only 3% of all scientific studies on TEK (Fig. 1). Considering that 40% of the global land surface is used by pastoralists and that there are an estimated hundreds of millions of pastoralists (Zinsstag et al. 2006, McGahey et al. 2014), despite its extent, global representation, and heterogeneity, pastoral TEK remains less studied than other groups. These figures align closely with several reports and scholarly articles that argue that pastoralist systems have received scant policy and research attention to date (e.g., Johnsen et al. 2019, Manzano-Baena et al. 2021). Taking into account the global relevance of pastoralism, with its extent and the large number of people depending on the practice, this observation supports calls for bringing more attention to pastoral TEK concerns (Molnár 2014, Fernández-Giménez 2000) that are in the agenda of the proposed International Year of Rangelands and Pastoralists for 2026. In line with our results, Brook and McLachlan (2008) showed that farmer and hunter-gatherer communities have received much more scholarly attention than other communities such as pastoralists. Additionally, the United Nations Environment Programme report on the number of studies on rangeland and pastoralism confirms that compared to other topics, research on rangelands and pastoralism is substantially lower (96,414 records from 71 million records), and that pastoral TEK studies account for only 1% of the total studies and projects on rangeland and pastoralism (Johnsen et al. 2019).

Fig. 1. Number of all traditional ecological knowledge (TEK) and pastoral TEK papers published from 1978 to 2019.



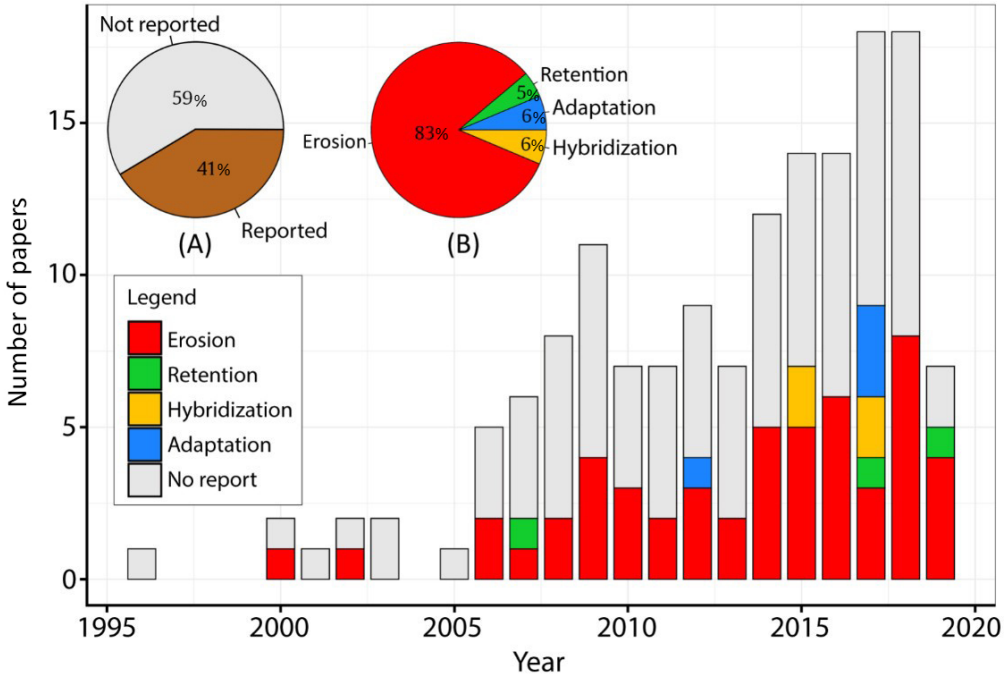
In terms of the geographical distribution of research on pastoral TEK (Fig. 2), most studies were conducted in Africa (50%), followed by Asia (30%), and Europe (14%). Studies on pastoral TEK were scant in Oceania (3%), South America (2%), and North America (1%). Overall, pastoral communities in 62 countries were studied, with Ethiopia (33 studies), Kenya (31), India (19), and China (18) being the most prominent ones.

Fig. 2. Number of pastoral traditional ecological knowledge studies per country based on the 288 papers reviewed.



Aswani et al. (2018) and Hanazaki et al. (2013) also found that Ethiopia, India, and China were hotspots for TEK-related research. In the case of scientific studies on rangelands and pastoralism (as a whole), China, Mongolia, Australia, Kenya, and Ethiopia had the highest share of studies (Johnsen et al. 2019). Our results also showed that 20 countries were represented by only a single study. Noting that pastoral identities may vary within countries, with several Indigenous groups or ethnicities recognized in many countries, single studies are certainly not representative enough. For example, of the 42 recognized ethnic groups in Kenya (many of which practice some form of pastoralism; see, for example, LPP [2021]), only nine groups were included in more than one study. In another example, yak herding is practiced among at least 31 ethnic groups in the Asian highlands, yet only a few studies of some ethnic groups were available. In Buthan and Tajikistan, for instance, where together

Fig. 3. Frequency of papers meeting review criteria by year considering traditional ecological knowledge (TEK) transition. (A) relative frequency of papers reporting TEK transition; (B) relative frequency of papers reporting different types of transition.



five ethnic groups are active in yak herding, only two general papers were found, and neither of them focused specifically on yak herding (Kassam 2009, Wu et al. 2014).

We found that some countries with large pastoral populations (e.g., Kazakhstan, Yemen, Somalia, and Uzbekistan) were not represented in the literature. This also extends to countries such as Central African Republic, Uruguay, or Eswatini, where more than 50% of the land is categorized as rangelands (Johnsen et al. 2019). This could be related to language barriers in science; much research written in French, Spanish, and Russian was not included in this study. We acknowledge that overlooking such literature can bias outcomes of evidence synthesis and lead to only a partial understanding of pastoralism at the global level.

Knowledge domains and pastoral mobility types are unevenly studied

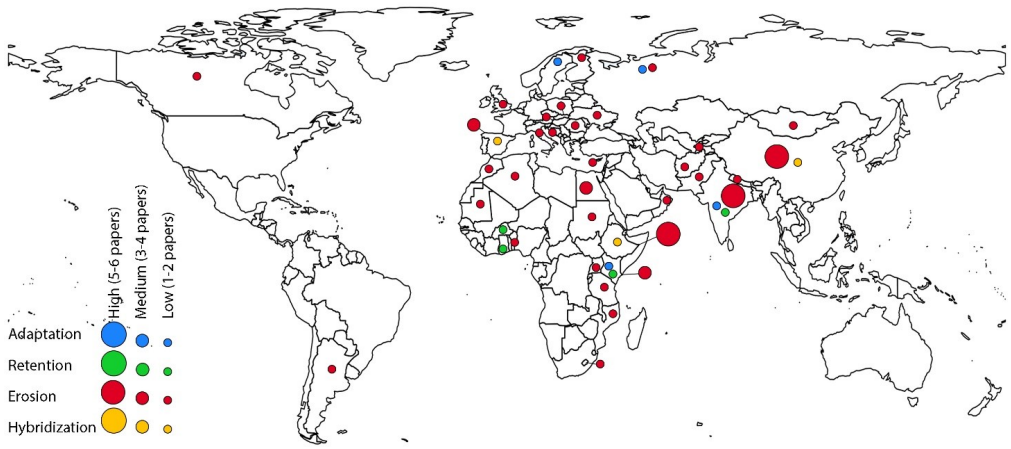
Similar attention has been paid to five major TEK domains related to herd and livestock management knowledge, forage and medicinal plant knowledge, and knowledge of landscape and wildlife (i.e., 73, 75, 70 studies, respectively). Interestingly, despite growing research interest in pastoral vulnerability to climate change, pastoral TEK about climate has received relatively scant scholarly attention, with only 15 studies on climate-related knowledge domains. This knowledge is vital to vulnerability and adaptation assessment, and confronts policy-makers with many research gaps (Ahearn et al. 2019). Pastoral TEK regarding climate and weather forecasting has enabled pastoralists to adjust their seasonal movement and cope with changes in precipitation and temperature, which dramatically affect the variability and availability of forage, fodder, and water sources (Nkuba et al. 2019). Also, the integration of climate-related TEK, which is based on a variety of biological, cultural, and astrological indicators, with scientific forecasts could improve the accuracy, uptake, and application of weather forecasting by locals (Reyes-García et al. 2015, Radeny et al. 2019).

The papers reviewed often lacked information regarding the type of pastoral way of life and/or mobility systems. Of the 58% of papers that did provide information on mobility types, most focused on nomadic (56%); fewer focused on transhumant (32%) and sedentary (25%) systems. When considering domains of knowledge and pastoralism types, it was less clear whether representativeness was even. It seems that ethnographic studies that addressed TEK tended to focus on groups that live more traditionally and have been less exposed to globalization; thus, this could reflect the greater attention paid to nomadic systems.

Transition in pastoral traditional ecological knowledge: erosion versus retention, adaptation, and hybridization

Transitions in pastoral TEK were addressed in 41% of the 152 papers reviewed in detail (Fig. 3A). Each of the four types of knowledge transition (i.e., retention, erosion, hybridization, and adaptation) was mentioned in at least one paper; erosion of knowledge was the transition type most often reported (83%). Retention, hybridization, and adaptation were each mentioned in 6% or less of the papers (Fig. 3B). Of all the transitions reported, 35% were based on robust empirical evidence, 17% were anecdotal, and 48% relied on weak empirical footing, as no traceable form of evidence was provided in the paper. In general, the interest in studying transitions in pastoral TEK is growing in a similar way as the number of studies in pastoral TEK (Fig. 3).

Fig. 4. Number of studies reporting traditional ecological knowledge transition types (based on 63 papers).



TEK erosion was commonplace globally but was most often reported in Asia and East Africa (Fig. 4). In Europe, Asia, and Africa, 55%, 53%, and 31% of the total number of studies, respectively, reported some form of TEK transition. Reported transition showed Ethiopia, India, China, Kenya, Egypt, and Spain with more reports of erosion. Although comparing the status of TEK transition among countries is difficult because research effort is far from homogenous across countries, it is important to highlight that TEK erosion is reported in most of the studied countries, even in biologically and culturally diverse regions.

Knowledge erosion was reported in similar frequency for all five major knowledge domains. However, we found a greater relative frequency for the domains Herd/Livestock (42%) and Forage/Medicine (44%) (Fig. 5). All domains reported at least 25% for erosion of pastoral TEK. Without considering retention of TEK as a "change", the highest frequency for any type of TEK transition was reported for the Forage/Medicine (48%) and Social-cultural (47%) domains. Hybridization and adaptation were reported for only three knowledge domains each. The small number of available studies made it difficult to find robust global patterns.

From all the studies in which the type of pastoral system was mentioned, nomadic, transhumant, and sedentary systems (45% [24 papers], 33% [18 papers], and 22% [12 papers], respectively) were mentioned to be affected by some form of TEK transition (Fig. 5). In all three pastoral system types, erosion was the most often reported transition, and in most cases, retention, adaptation, and hybridization was found only in a few cases. Further research is needed to obtain a better and more representative understanding of the differences in knowledge transitions across different pastoral mobility systems.

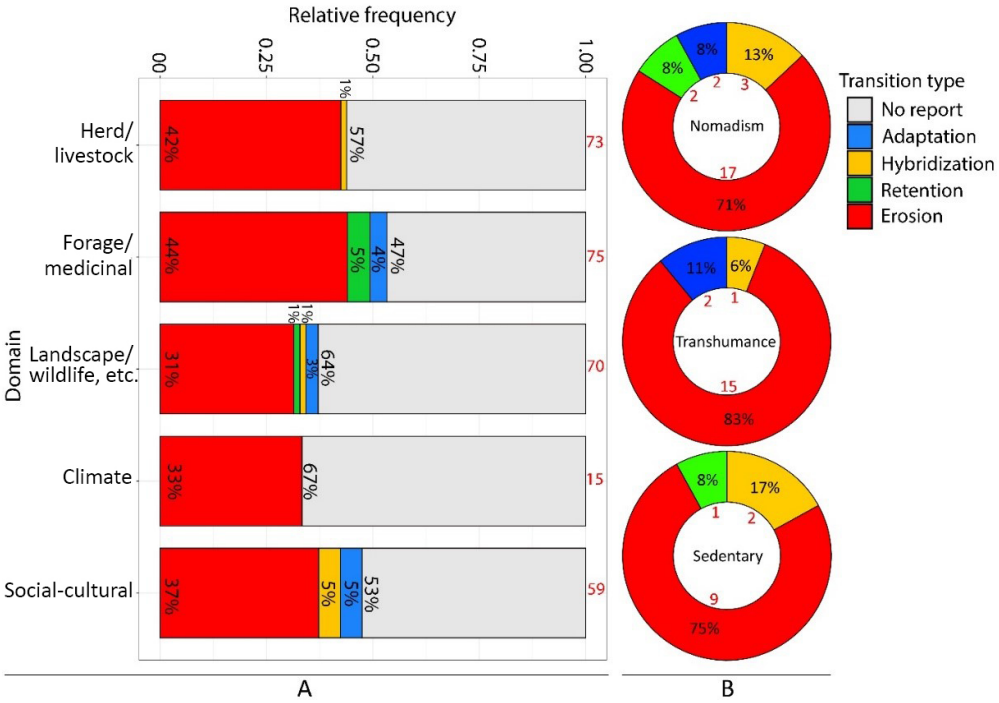
Regardless of the lifestyle that pastoralists have (nomadism, transhumance, or sedentarism), loss of unnecessary knowledge and accumulation of new knowledge occurs with time and new practices. In other words, if a community has a sedentary lifestyle, it does not mean that they have lower TEK compared to nomads (Nedelcheva et al. 2017). However, shifting from one lifestyle to another could affect the knowledge that pastoralists are "carrying" with themselves (Duenn et al. 2017, Bussmann et al. 2018). The slightly greater erosion of knowledge reported for transhumant and sedentary systems could suggest that some of these communities are increasingly shifting to sedentary lifestyles. Therefore, due to the shift, and at least regarding some knowledge domains that are less applicable in the new lifestyle, the volume of pastoral TEK may decline (Dong et al. 2011, Bussmann et al. 2018).

The relatively greater number of papers that reported pastoral TEK erosion may be alarming for local, national, and international organizations that are aiming to promote sustainable use of rangelands and biocultural conservation of pastoral social-ecological landscapes. Aswani et al. (2018) and Hanazaki et al. (2013) reported the same result when conducting reviews on TEK transition among other communities such as farmers, hunter-gatherers, and fishers, and found that 77% and 57% of the papers reviewed reported TEK erosion, respectively.

As pastoral communities are being impacted by changes in climate, culture, technology, social-economic conditions, and policies at various scales (Reid et al. 2014), so too are their TEK systems. On one hand, erosion of pastoral TEK could be the consequence of the change; on the other hand, it could be the very driver of the change. For example, recent changes in plant diversity in Eastern Africa have caused the extinction of some plant species that were used in weather forecasting and prediction by Borana pastoralists in southern Ethiopia and northern Kenya. This extinction has led to the erosion of knowledge about these plant species. Losing the knowledge of weather forecasting has affected pastoral migration and movement abilities, which consequently debilitates the Borana's resilience to climate change (Radeny et al. 2019).

Due to the low number of studies and the research gaps we identified, knowledge transition patterns found in this review cannot be considered indicative of what is happening to pastoral TEK globally. Importantly, not a single study addressed all types of knowledge domains or compared all types of pastoral mobility systems regarding knowledge transitions. Only one knowledge

Fig. 5. A: Types of traditional ecological knowledge (TEK) transition reported for each major knowledge domain. B: TEK transition reported for different pastoral mobility types (black labels show percentages; red labels show the total number of papers).



domain was covered in 49% of the studies, and only two were addressed in 37% of the studies. Also, regarding the subdomains (Table 1), 91% of studies focused on less than three subdomains, while approximately 2% of studies covered six subdomains: Oteros-Rozas et al. (2013), Fernández-Giménez (2015), and Jandreau and Berkes (2016).

Another research gap in pastoral TEK studies is that although different transitional types have been reported for pastoral TEK, most of the studies have labeled TEK transition as erosion. As it was also emphasized by Tian (2017), TEK transition is evaluated primarily linearly as gain or loss; however, adaptation and hybridization of TEK are also possible—and highly relevant—changes. Researchers have often assessed the transition of pastoral TEK by comparing the volume of knowledge between or within generations (Oteros-Rozas et al. 2013, Salpeteur et al. 2015) and have referred to the lower volume of knowledge of the younger generation as erosion. However, compared to the older generation, the new generation could be less knowledgeable, for instance, about plant species that used to be dominant in the region, while having gained more knowledge about a newly arrived invasive species (Duenn et al. 2017). In another case, changes in herd composition from cattle to sheep that are driven by market demands have resulted in the new generation having more knowledge about sheep but fading knowledge regarding cattle, which is no longer applicable based on the new circumstances (Adriansen 2008). We argue that erosion of TEK concerning specific subdomains should not automatically imply the overall downward trend in communities' TEK. In fact, this change may originate from adaptive strategies and/or hybridization of knowledge due to exposure to other knowledge systems.

Examples of adaptation, hybridization, and retention of pastoral traditional ecological knowledge

Adaptation, although rarely studied explicitly (only four studies, 6% of the sample), has been reported both in nomadic and transhumant systems (Fig. 5), and across several knowledge domains (i.e., Social-cultural, Forage/Medicine, and Landscape/Wildlife). Yet, no adaptation has been reported for Herd/Livestock and Climate knowledge domains. Knowledge adaptation among pastoralist societies is largely underrepresented in the scholarly literature, particularly so if we consider that pastoralism is a resilient and highly adaptive livelihood and the most widespread land use on Earth (Reid et al. 2014). Adaptive changes in pastoral practices (see, for example, Duenn et al. [2017]) deserve much more scholarly and policy attention than they have received to date. Similarly, hybridization has been poorly studied, but we found examples of hybridization across pastoral mobility types and some knowledge domains, though with no clear patterns. Knowledge retention was also mentioned in three studies. In one study, the new generation was found to carry greater knowledge regarding one domain compared to the elder generation (see Naah and Guuroh [2017] for more information). To illustrate differences between adaptation, hybridization, and retention, Table 2 presents some case studies.

Major drivers of traditional ecological knowledge transition: pastoral knowledge is threatened

Causality flows in multiple directions and is iterative: loss of TEK changes the ecosystems that were shaped by it, and the

Table 2. Examples of adaptation and hybridization of pastoral traditional ecological knowledge (TEK) from different parts of the world.

Type	Reference
Adaptation: Pastoralists cope with changes in environment and social-economic conditions through adaptive strategies. Implementation of new practices is based on adaptive knowledge that makes the adjustment of pastoral systems to changes effective.	
Kenya: Due to diet changes among Maasai pastoralists, shifting from milk and meat centered to more agricultural crops, girls' activities and TEK regarding firewood collection have expanded and adapted by putting more time into wood collection and involvement of younger children. Also, with developing formal schooling in the region, firewood collection has been adjusted to a shorter period prior to school time.	Tian (2017)
Russia: After the collapse of the Soviet Union, Siberian Evenki people who were living in the Arctic forest tundra region of northwestern Yakutia changed their basic subsistence from reindeer herding to a combination of herding and hunting due to environmental change, political regime change, and economic development.	Takakura (2012)
Bolivia: As trends of diminishing water availability are recorded across the Andes, mountain peatlands (bofedales), which are the main pastureland for camelid pastoralists, are becoming more degraded and drier. Consequently, Andean pastoralists have adopted collective irrigation practices to rehabilitate these pastures which were used in the past.	Yager et al. (2019)
Benin: Fulbe pastoralists' perception and TEK regarding animal genetic breeds have adapted to new environmental and social-political regulations. For instance, with encroachment of farmlands, which is resulting in the loss of grazing areas and watering points, cattle herders' preferences for breeds are changing from high milk and meat production to breeds that are tolerant to hunger and long walks is search for forage. Also, scarce grazing land had made pastoralists use specific breeds that are good at escaping from agents responsible for illegal grazing.	Tamou et al. (2018)
Hybridization: Exposure to other knowledge systems and technologies leads to the development of hybrid knowledge and practices that are based on them. This exposure may contribute to changes in management but also to a change of values pastoralists follow. Hybridization—whether done voluntarily or involuntarily—is another strategy to make persistency of pastoral systems possible.	
China: In the past, Tibetan herders' traditional knowledge influenced by Buddhist teaching viewed yaks as sentient beings that should not be slaughtered; however, being subjected to market-driven logic, slaughtering is currently considered a necessary process. The contemporary forces have resulted in the hybrid indigenous knowledge of Tibetan pastoralists in a way that most of them do not reject one view for the other; rather, they employ both.	Gaerrang (2017)
Spain: Younger Spanish shepherds in the Cantabrian Mountains are exposed to external sources of training and information, including the Internet, which has resulted in new understanding regarding scavengers and their role in other nature-based subsistence, such as nature tourism. Therefore, the population of Griffon Vultures (*Gyps fulvus*) has increased due to this hybridization of knowledge.	Morales-Reyes et al. (2019)
Australia: Indigenous cattle herders' practices in Oriners Station (Indigenous-owned pastoral lease east of Kowanyama) have been influenced by operational knowledge of national parks and contemporary management, which has led to hybridization of their knowledge. Currently, pastoralists compromise with other involved stakeholders such as conservationists and scientists in implementing their traditional-based practices such as horse riding.	Barber et al. (2014)
Uganda: As the result of being exposed to modern weather prediction techniques and information, pastoralists' knowledge in the Rwenzori region regarding predicting and forecasting weather features is currently a hybrid knowledge based both on scientific and traditional knowledge.	Nkuba et al. (2019)
Retention: Knowledge transmission is constantly occurring without any gap within or between generations.	
Kenya: Despite the gradual shift from a nomadic to sedentary lifestyle, pastoral knowledge regarding botanical features of plant species was uniformly shared across age and gender, and source of livelihood.	Stave et al. (2007)
India: Children of the semi-nomadic Gujjar tribe (buffalo herders) in the high altitude of the Western Himalaya still accompany their fathers and elder generation to the higher altitude and learn about useful plant species through observation.	Rana et al. (2019)
Ghana; Burkina Faso: Free forage plant listing ability of the elder generation was the same as younger generation. In some cases, it was shown that younger generations carry greater knowledge pertaining to forage species than the elders, which showed the intrinsic flexible nature of pastoral TEK acquisition and transmission.	Naah and Guuroh (2017)

opportunities for practicing TEK as an expression of culture are constrained by that new ecological trajectory. As a result, the loss itself, the cause of the loss, and the consequences of the loss are often interwoven; therefore, causes of TEK transition cannot be directly associated to simple factors. Nevertheless, we identified 13 drivers that are affecting pastoral TEK transitions, which were mentioned individually or in combination in the reviewed papers (Table 3). Social-cultural changes (13 citations), formal schooling (11 citations), abandonment of pastoral activities (11 citations), and transition to a market economy (10 citations) were the most often reported causes.

Social-cultural changes have been reported in several studies as a major driver of transition in TEK systems (Cristancho and Vining 2009, McCarter and Gavin 2014). Although pastoralism has a checkered history globally, social-cultural systems have been more exposed to diverse changes in the last century than in former times. Shifting from community-based management to governmental or state-based management has often come at the expense of local governance and autonomy (Reid et al. 2014). On this account, the share of top-down decision-making in rangeland management increased, which caused insurmountable barriers in the implementation of pastoral practices. Customary governance, which is underpinned by a dynamic network of vertical, horizontal, oblique, and retroactive transmission and sharing of pastoral TEK, has been drastically eroded as a result of rapid socio-political changes and land reform laws, globally (Greiner 2017). As a result, knowledge and experience input from elders and knowledgeable pastoralists devaluated (Tang and Gavin 2015). A Maasai cattle herder said "Before, we had a warming fire in the middle of the homestead. When the cows come in the evening all the shepherds have to come with the elders. The shepherds would narrate the story…" (Jandreau and Berkes 2016:9). Furthermore, in many places, pastoralism as a livelihood has lost its social status and value. A stockman from Spain said "It has been a fight against the current being a stockman, my stubbornness, and yet I see that it's in my son's blood" (Fernández-Giménez and Estaque 2012:297).

Table 3. Drivers of traditional ecological knowledge transition (numbers in parenthesis indicate the number of studies; the 3-letter abbreviations indicate the country in which the driver was reported).

Driver	References
Social-cultural changes (13): China, India, Spain, Kenya, Mongolia, Argentina, Benin, Ethiopia, Nepal, Oman	Tang and Gavin (2015); Salpeteur et al. (2015); Fernández-Giménez and Estaque (2012); Jandreau and Berkes (2016); Fernandez-Gimenez (2000); Ladio and Lozada (2009); Oteros-Rozas et al. (2013); Gaoue and Ticktin (2009); Belayneh et al. (2012); Seid et al. (2016); Dong (2017); Singh et al. (2015); Salman and Kharusi (2014)
Formal schooling (11): China, Kenya, Nepal, Pakistan, Spain, Egypt, Sudan, India, Ethiopia, Tanzania, Uganda	Tang and Gavin (2015); Bruyere et al. (2016); Jandreau and Berkes (2016); Spoon (2011); Aziz et al. (2018); Oteros-Rozas et al. (2013); Hobbs et al. (2014); Dutt et al. (2015); Radeny et al. (2019); Hopping et al. (2016); Kuriyan (2002)
Abandonment of pastoral activities (11): Kenya, Argentina, Spain, Hungary, Cyprus, Benin, Algeria, Mauritania, Morocco, Italy, India	Bruyere et al. (2016); Jandreau and Berkes (2016); Ladio and Lozada (2009); Oteros-Rozas et al. (2013); Molnár (2014); Della et al. (2006); Gaoue and Ticktin (2009); Easdale and Aguiar (2018); Volpato et al. (2015); Rippa et al. (2011); Singh et al. (2018)
Transition to a market economy (10): Mongolia, Spain, China, Afghanistan, Tajikistan, Lesotho, Pakistan, India, Kenya	Fernandez-Gimenez (2000); Oteros-Rozas et al. (2013); Hernández-Morcillo et al. (2014); Liu (2013); Kassam (2009); Morojele (2017); Post (2018); Raziq et al. (2010); Singh et al. (2015); Kuriyan (2002)
Policies and regulations (8): China, Spain, Mongolia; Hungary, India, Nepal, Pakistan, Finland	Tang and Gavin (2015); Fernández-Giménez and Estaque (2012); Fernández-Giménez (2000); Oteros-Rozas et al. (2013) (2015); Molnár (2014); Dong (2017); Raziq et al. (2010); Turunen et al. (2016)
Urbanization (8): China, Pakistan, Ethiopia, Tanzania, Uganda, Cyprus, Egypt, Sudan, Argentina, India, Nepal)	Tang and Gavin (2015); Aziz et al. (2018); Radeny et al. (2019); Della et al. (2006); Andersen et al. (2014); Easdale and Aguiar (2018); Dong (2017); Raziq et al. (2010)
Subsistence diversification (7): Kenya, Nepal, China, Lesotho, India, Pakistan)	Jandreau and Berkes (2016); Spoon (2011); Nyima and Hopping (2019); Liu (2013); Morojele (2017); Singh et al. (2018); Raziq et al. (2010)
Modernization and technology (6): Kenya, Pakistan, Spain, India, Finland	Bruyere et al. (2016); Aziz et al. (2018); Oteros-Rozas et al. (2013); Dutt et al. (2015); Seid et al. (2016); Turunen et al. (2016)
Environmental and climatic changes (6): Kenya, Ethiopia, Tanzania, Uganda, Egypt, Pakistan, Finland	Speranza et al. (2010); Radeny et al. (2019); Yacoub (2018); Raziq et al. (2010); Feyssa et al. (2012); Turunen et al. (2016)
Sedentarization (6): Egypt, Sudan, China, Afghanistan, Tajikistan, Algeria, Mauritania, Morocco, Pakistan	Hobbs et al. (2014); Liu (2013); Kassam (2009); Volpato et al. (2015); Homann et al. (2008); Raziq et al. (2010)
Agricultural expansion (5): Afghanistan, Tajikistan, China, Italy, India	Kassam (2009); Liu (2013); Homann et al. (2008); Rippa et al. (2011); Singh et al. (2018)
Privatization (4): China, Kenya, Mongolia, India, Nepal	Tang and Gavin (2015); Jandreau and Berkes (2016); Fernandez-Gimenez (2000); Dong (2017)
Deagrarianization (1): Argentina	Ladio and Lozada (2009)

Formal schooling has also been mentioned as an important driver of TEK erosion in groups other than pastoralists (Harvey 2013, Reyes-García et al. 2013). Consolidation and development of formal schooling services detached children's connections with pastoral activities and forced the children to live away from pastoral lands. It even forced some pastoral families to abandon their lifestyle and live where school services were available (Tang and Gavin 2015). Thus, the dynamic nature of nomadism and a transhumance lifestyle increases the challenge of formal education for pastoralists' children compared to children in permanently settled agriculturalist communities (Bruyere et al. 2016). Also, the lack of pastoral TEK in the formal school curricula is another negative point that increases the distance between the new generation and the previous cultural lifestyle (see Reyes-García et al. [2010] for a thorough discussion of this topic). Therefore, pastoral TEK among children who become distanced from a constant presence in nature gradually vanishes (Bruyere et al. 2016). "Old people have lots of experiences, and young people have good educations" (Hopping et al. 2016:32). [Educated children that live in the town] "cannot live in the desert anymore" (Hobbs et al. 2014:2939). Countries where formal schooling is negatively affecting pastoral TEK can consider educational systems and curricula through which this challenge can be partially addressed. For example, the Mongolian education system has made traditional pastoral history and culture the basis of many textbooks in a genuine attempt to teach new generations about the important cultural, social, economic, and environmental values of pastoralism. As an example, pupils in Grades 2-3 read the famous poem in their Social Science class: "Dung smoke pouring forth, I was born in a herder's home, on the wilderness steppe, I think of my native land" (Gardelle and Zhao 2019:12). Mobile schools also can help reach formal educational goals while keeping pastoral TEK and practices alive for the new generation of pastoralists. Tribal schools initially established in Iran by Mohammad Bahman Beigi and reinvigorated in the post-revolutionary era could serve as a good example (Annamoradnejad and Lotfi 2010). Nevertheless, it must be emphasized that achieving a proper educational model that feeds the sustainability of pastoral social-ecological systems while also satisfying the changing modern world requires participatory involvement of pastoralists and local decision-makers (Dyer and Echessa 2019).

CONCLUSION

Constant long-term presence and monitoring by pastoralists of their social-ecological systems have enabled them to develop rich bodies of knowledge and practices about their local ecologies. Understanding this knowledge is pivotal for sustainable

management and nature conservation. Furthermore, several global reports such as IPBES (2019), Karki et al. (2017), and an extensive body of scholarly literature (Fernández-Giménez 2015, Molnár et al. 2020, Fernández-Llamazares et al. 2021) have already shown that traditional, Indigenous, and local communities, including many pastoralist societies, are not only interested in the benefits that they gain from nature, but they are also concerned about other components of social-ecological systems such as flora, fauna, soil, water, etc. and the conservation and sustainable use of them. Previous studies have raised awareness of potential important gaps in pastoral TEK. We report that only 3% of TEK studies globally addressed pastoral TEK, thus identifying important research gaps. Our study also identifies where (geographically, knowledge domains, types of change) those gaps are, thus contributing to preparations for the largely endorsed proposal of the International Year of Rangelands and Pastoralists for 2026 (https://iyrp.info/). One of the primary goals of the planned International Year of Rangelands and Pastoralists is pursuing and addressing the challenges of pastoralists' traditional knowledge. Documenting the transition status of pastoralists' knowledge can help the United Nations as well as different governmental and nongovernmental organizations understand the current condition of pastoral TEK systems. Furthermore, a global assessment can provide fundamental information upon which decision-making and planning can be undertaken to eliminate the obstacles that limit pastoralists in executing their TEK-based practices. Despite the fact that pastoralists carry knowledge in several domains, the limited research on pastoral TEK has focused more often on Herd/Livestock, Forage/Medicine, and Landscape/Wildlife; Climate and Socio-cultural domains are less studied. International planning and management for rangeland and pastoralism is not possible when our knowledge pertaining to pastoral TEK is not detailed enough.

Notwithstanding the number of studies on pastoral TEK, our review showed that knowledge erosion may be the dominant type of knowledge transition occurring among pastoralists worldwide. However, knowledge adaptation and hybridization were shown to be critical in the implementation of solutions to new social-ecological challenges in many areas of the world, despite the fact that they continue to be under-researched. Changes in pastoral TEK are caused by many interwoven drivers. Although documentation of pastoral TEK in scientific papers and reports is a helpful start, safeguarding pastoral TEK requires a fundamental shift across sectors in how such knowledge systems are recognized, affirmed, and sustained. We argue that research on pastoral TEK could help advance policy on pastoralism (e.g., by highlighting the ways in which pastoralism contributes to planetary sustainability, and the contexts that facilitate or undermine such contributions). More specifically, research on TEK dynamics could bring into focus the different transition types and help avoid the common mischaracterization of all knowledge changes as symptoms of vulnerability and loss. By focusing on knowledge hybridization and adaptation, future research efforts could pay justice to the immense and powerful cultural continuity that is a hallmark of pastoral societies worldwide, and affirm their ongoing struggles to foster social-ecological resilience over the long run.

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Data Availability:

Data/code available upon request because of privacy/ethical restrictions.

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Table A1.1. All 288 papers reviewed (title and country to provide figure 2)

Paper's _code	Title	Country
115	Conservation and monitoring of a persecuted African lion population by Maasai warriors	Kenya
140	Degradation and re-emergence of the commons: The impacts of government policies on traditional resource management institutions in China	China
136	Drivers of forage availability: An integration of remote sensing and traditional ecological knowledge in Karamoja sub-region, Uganda	Uganda
92	Ethnobotanical knowledge acquisition during daily chores: the firewood collection of pastoral Maasai girls in Southern Kenya	Kenya
141	Forgetting fire:Traditional fire knowledge in two vchestnut forest ecosystems of the Iberian Peninsula and its implications for European fire management policy	Spain
150	When Knowledge Follows Blood Kin Groups and the Distribution of Traditional Ecological Knowledge in a Community of Seminomadic Pastoralists, Gujarat (India)	India
220	Pyrenean Pastoralists' Ecological Knowledge: Documentation and Application to Natural Resource Management and Adaptation	Spain
105	A comparison of traditional plant knowledge between students and herders in northern Kenya	Kenya
159	A shepherd has to invent: Poetic analysis of social-ecological change in the cultural landscape of the central Spanish Pyrenees	Spain
31	Another vision of sound tree and forest management: Insights from traditional ash shaping in the Moroccan Berber mountains	Morocco
101	Continuity and change within the social-ecological and political landscape of the Maasai Mara, Kenya	Kenya
233	The Heterogeneity of Khumbu Sherpa Ecological Knowledge and Understanding in Sagarmatha (Mount Everest) National Park and Buffer Zone, Nepal	Nepal
58	Traditional uses of medicinal plants used by Indigenous communities for veterinary practices at Bajaur Agency, Pakistan	Pakistan
366	The role of Mongolian nomadic pastoralists' ecological knowledge in rangeland management	Mongolia
315	Traditional ecological knowledge of a riverine forest in Turkana, Kenya: implications for research and management	Kenya
282	Human ecology, ethnobotany and traditional practices in rural populations inhabiting the Monte region: Resilience and ecological knowledge	Argentina
261	Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya	Kenya
212	Traditional ecological knowledge among transhumant pastoralists in Mediterranean Spain	Spain
184	Traditional Ecological Knowledge in Europe: Status Quo and Insights for the Environmental Policy Agenda	NA
182	Perception and Management of Spatio-Temporal Pasture Heterogeneity by Hungarian Herders	Hungary
169	Acacia trees on the cultural landscapes of the Red Sea Hills	Egypt; Sudan
281	Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia	Russia
133	Comigrants and friends: Informal networks and the transmission of traditional ecological knowledge among seminomadic pastoralists of Gujarat, India	India
283	Community participatory landscape classification and biodiversity assessment and monitoring of	Kenya

	grazing lands in northern Kenya	
227	Ecological Conservation, Cultural Preservation, and a Bridge between: the Journey of Shanshui Conservation Center in the Sanjiangyuan Region, Qinghai-Tibetan Plateau, China	China
183	Herder Observations of Rangeland Change in Mongolia: Indicators, Causes, and Application to Community-Based Management	Mongolia
303	Herder Perceptions on Impacts of Range Enclosures, Crop Farming, Fire Ban and Bush Encroachment on the Rangelands of Borana, Southern Ethiopia	Ethiopia
310	Learning from local knowledge: modeling the pastoral nomadic range management of the Himba, Namibia	Namibia
11	Medicinal wild plants used by the Mongol herdsmen in Bairin Area of Inner Mongolia and its comparative study between TMM and TCM	China
235	Reindeer management during the colonization of Sami lands: A long-term perspective of vulnerability and adaptation strategies	Sweden
228	Tending for Cattle: Traditional Fire Management in Ethiopian Montane Heathlands	Ethiopia
	The sacred and the scientific: traditional ecological knowledge in Siberian river conservation	Siberia
62	Through the lens of a herder: insights into landscape ethno-ecological knowledge on rangelands in Namaqualand	South Africa
148	Oral traditional knowledge on medicinal plants in jeopardy among Gaddi shepherds in hills of northwestern Himalaya, J&K, India.	India
294	Participatory monitoring of biodiversity in East African grazing lands	Uganda
165	Communal institutions for the management of rangeland resources and dairy production in Taleghan Valley, Northern Iran	Iran
259	Remote Sensing and Local Knowledge of Hydrocarbon Exploitation: The Case of Bovanenkovo, Yamal Peninsula, West Siberia, Russia	Siberia
4	Indigenous knowledge for seasonal weather and climate forecasting across East Africa	Ethiopia; Tanzania; Uganda
292	Walking Behind the Old Women: Sacred Sakha Cow Knowledge in the 21st Century	Russia
363	Assessments of landscape level degradation in southern Ethiopia: pastoralists versus ecologists	Ethiopia
289	Indigenous Knowledge between Collapsion and Prospect of Genetic Conservation and Development	NA
175	Unexpected climate impacts on the Tibetan Plateau: Local and scientific knowledge in findings of delayed summer	China
36	Inuit Approaches to Naming and Distinguishing Caribou: Considering Language, Place, and Homeland toward Improved Co-management	Canada
180	Efficacy of Two Lion Conservation Programs in Maasailand, Kenya	Kenya
325	Long-term Abundance Patterns of Barren-ground Caribou Using Trampling Scars on Roots of Picea mariana in the Northwest Territories, Canada	Canada
286	Traditional livelihood based on sheep grazing in the Khangchendzonga national park, Sikkim	India
48	Analysis of observed and perceived climate change and variability in Arsi Negele District, Ethiopia	Ethiopia
181	Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso	Burkina Faso
28	This country just hangs tight: perspectives on managing land degradation and climate change in far west NSW	Australia
333	An ethnobotanical survey of wild edible plants of Paphos and Larnaca countryside of Cyprus	Cyprus

176	Traditional nomadic tending of trees in the Red Sea Hills	Egypt; Sudan
129	Rangeland degradation assessment: a new strategy based on the ecological knowledge of indigenous pastoralists	Iran
278	Fulani Knowledge of the Ecological Impacts of Khaya senegalensis (Meliaceae) Foliage Harvest in Benin and its Implications for Sustainable Harvest	Benin
19	Tibetan Lake Expansion from a Pastoral Perspective: Local Observations and Coping Strategies for a Changing Environment	China
301	Integration of herder knowledge and ecological methods for land degradation assessment around sedentary settlements in a sub-humid zone in northern Kenya	Kenya
214	Medicinal plants potential and use by pastoral and agro-pastoral communities in Erer Valley of Babile Wereda, Eastern Ethiopia	Ethiopia
73	Reimagining invasions: The social and cultural impacts of Prosopis on pastoralists in southern Afar, Ethiopia	Ethiopia
229	The Shift from Herding to Hunting among the Siberian Evenki	Siberia
263	Riders under storms: Contributions of nomadic herders' observations to analysing climate change in Mongolia	Mongolia
164	Turkana indigenous knowledge environmental sustainability and pastoralist lifestyle for economic survival	Kenya
53	Knowledge and community resilience in rangelands recovery: the case of Wadi Allaqi Biosphere Reserve, South Eastern Desert, Egypt	Egypt
280	Evaluation of Local Ecological Knowledge as a Method for Collecting Extensive Data on Animal Abundance	Spain
80	Climate Change and Variability in Semiarid Palapye, Eastern Botswana: An Assessment from Smallholder Farmers' Perspective	Botswana
252	Assessing Resource Dependency on the Rangelands as a Measure of Climate Sensitivity	Australia
35	From traditional knowledge to novel adaptations of transhumant pastoralists the in face of new challenges in North Patagonia	Argentina
91	Exploring local knowledge and perceptions on zoonoses among pastoralists in northern and eastern Tanzania	Tanzania
226	Pastoralists' Perception and Ecological Knowledge on Savanna Ecosystem Dynamics in Semi-arid Botswana	Botswana
67	Contested understandings of yaks on the eastern Tibetan Plateau: market logic, Tibetan Buddhism and indigenous knowledge	China
260	Linking local ecological knowledge and habitat modelling to predict absolute species abundance on large scales	Spain
143	Misreading the Arctic landscape:Apolitical ecology of reindeer, carrying capacities, and overstocking in Finnmark, Norway	Norway
111	Communication for the development of pastoralism	
323	Behaviour of goats, sheep and cattle and their selection of browse species on natural pasture in a Sahelian area	Burkina Faso
94	Himalayan Grasslands: Indigenous Knowledge and Institutions for Social Innovation	China; India; Nepal
331	Use of participatory epidemiology to compare the clinical veterinary knowledge of pastoralists and veterinarians in East Africa	Sudan; Kenya
119	The use of indigenous climate forecasting methods by the pastoralists of Northern Kenya	Kenya

318	Tracking wildebeest, locating knowledge: Maasai and conservation biology understandings of wildebeest behavior in Northern Tanzania	Tanzania
132	Integrating local pastoral knowledge, participatory mapping, and species distribution modeling for risk assessment of invasive rubber vine (Cryptostegia grandiflora) in Ethiopia's Afar region	Ethiopia
102	Community perceptions on spatio-temporal land use changes in the Amboseli ecosystem, southern Kenya	Kenya
322	Indigenous rangeland resource management in the mountainous areas of northern Nepal: a case study from the Rasuwa District	Nepal
199	Wild plant folk nomenclature of the Mongol herdsmen in the Arhorchin national nature reserve, Inner Mongolia, PR China	China
240	Human stewardship or ruining cultural landscapes of the ancient Tula wells, southern Ethiopia	Ethiopia
87	Alignment between values of dryland pastoralists and conservation needs for small mammals.	Australia
268	Origins of Travelling Stock Routes. 1. Connections to Indigenous traditional pathways	Australia
97	Collaborative processes for exploring rural futures: The Exploring Futures Platform	New Zealand
272	Viewing Change Through the Prism of Indigenous Human Ecology: Findings from the Afghan and Tajik Pamirs	Afghanistan; Tajikistan
107	Coupled Socio-Environmental Changes Triggered Indigenous Aymara Depopulation of the Semiarid Andes of Tarapacá-Chile during the Late 19th-20th Centuries	Chile
130	Local knowledge production, transmission, and the importance of village leaders in a network of Tibetan pastoralists coping with environmental change	China
147	Ethnoveterinary of Sahrawi pastoralists of Western Sahara: camel diseases and remedies	Algeria; Mauritania; Morocco
25	Forest Fire and Indigenous Sami Land Use: Place Names, Fire Dynamics, and Ecosystem Change in Northern Scandinavia	Sweden
114	Meadow up a tree: Feeding flocks with a native ash tree in the Moroccan mountains	Morocco
284	Institutional development for sustainable rangeland resource and ecosystem management in mountainous areas of northern Nepal	Nepal
300	The effect of development interventions on the use of indigenous range management strategies in the Borana Lowlands in Ethiopia	Ethiopia
85	Species composition determines forage quality and medicinal value of high diversity grasslands in lowland England	England
65	Exploring knowledge and management practices on ticks and tick-borne diseases among agro-pastoral communities in Southern Highlands, Tanzania	Tanzania
234	The impact of agro-pastoral abandonment on the Rock Partridge Alectoris graeca in the Apennines	Italy
262	Learning the indigenous knowledge and biodiversity through contest: A participatory methodological tool of ecoliteracy	India
210	Ethno-veterinary practices for ephemeral fever of Yak: A participatory assessment by the Monpa tribe of Arunachal Pradesh	India
330	Indigenous ecological knowledge of Borana pastoralists in southern Ethiopia and current challenges	Ethiopia
238	Husbandry practices of El-Kababish camel herders: case study north Kordofan State, Sudan	Sudan
86	Husbandry practices of El-Kababish camel herders: case study north Kordofan State, Sudan	Lesotho
201	Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability	Mozambique

47	Climate change and cultural heritage in western Mongolia	Mongolia
90	Collecting Ophiocordyceps sinensis: an emerging livelihood strategy in the Garhwal, Indian Himalaya	India
178	The interplay of knowledge, attitude and practice of livestock farmers' land management against desertification in the South African Kalahari	South Africa
209	The good shepherd: remedying the fencing syndrome	South Africa
204	'Everybody knows', but the rest of the world: the case of a caterpillar-borne reproductive loss syndrome in dromedary camels observed by Sahrawi pastoralists of Western Sahara	Mauritania; Algeria
223	Accuracy of pastoralists' memory-based kinship assignment of Ankole cattle: a microsatellite DNA analysis	Uganda
45	Grazing and rangeland management: Trans-human adaptations by Brokpa community in fragile ecosystems of Arunachal Pradesh	India
9	Adaptation to climate change using indigenous weather forecasting systems in Borana pastoralists of southern Ethiopia	Ethiopia
302	Livestock grazing behaviour along a degradation gradient in the Somali region of eastern Ethiopia	Ethiopia
146	Ethnoveterinary medicines used by goat keepers in Marwar region of Rajasthan, India	India
3	Local Knowledge for Addressing Food Insecurity: The Use of a Goat Meat Drying Technique in a Rural Famine Context in Southern Africa	Mozambique
277	Efficacy of Integrating Herder Knowledge and Ecological Methods for Monitoring Rangeland Degradation in Northern Kenya	Kenya
256	Quantitative ethnobotany of medicinal plants used by Kara and Kwego semi-pastoralist people in lower Omo River Valley, Debub Omo Zone, Southern Nations, Nationalities and Peoples Regional State, Ethiopia	Ethiopia
314	Pastoralists' perceptions and realities of vegetation change and browse consumption in the northern Kalahari, Namibia	Namibia
258	Ethnoveterinary treatments by dromedary camel herders in the Suleiman Mountainous Region in Pakistan: an observation and questionnaire study	Pakistan
41	In the light of change: a mixed methods investigation of climate perceptions and the instrumental record in northern Sweden	Sweden
32	Turning the herding lifestyle into a learning opportunity: Experiences from Lesotho	Lesotho
34	Investigating criteria for valuation of forage resources by local agro-pastoralists in West Africa: using quantitative ethnoecological approach	Ghana; Burkina Faso
81	Can pastoral communities offer solutions for conserving the Endangered Grevy's zebra Equus grevyi at the periphery of its range?	Kenya
177	Past and Present Winter Feeding of Reindeer in Finland: Herders' Adaptive Learning of Feeding Practices	Finland
43	Ethnomedicinal applications of animal species by the local communities of Punjab, Pakistan	Pakistan
338	Plant Biodiversity and Ethnobotany of Borana Pastoralists in Southern Oromia, Ethiopia	Ethiopia
104	Changing year-round habitat use of extensively grazing cattle, sheep and pigs in East-Central Europe between 1940 and 2014: Consequences for conservation and policy	Hungary; Croatia; Serbia; Romania; Ukraine; Slovakia

161	Local perceptions of rangeland degradation and climate change in the pastoral society of Qinghai-Tibetan Plateau	China
222	Pastoralists' indigenous selection criteria and other breeding practices of the long-horned Ankole cattle in Uganda	Uganda
63	Feeding flocks on rangelands: insights into the local ecological knowledge of shepherds in Boulemane province (Morocco)	Morocco
15	Knowledge, perceptions and experiences of trachoma among Maasai in Tanzania: Implications for prevention and control	Tanzania
44	Ethnobotanical knowledge of pastoral community for treating livestock diseases in Somali regional state, eastern Ethiopia	Ethiopia
296	Understanding pastoral mobility: the case of Senegalese Fulani	Senegal
123	Information sharing and climate risk management among Senegalese agropastoralists	Senegal
71	Rabari shepherds and the mad tree: the dynamics of local ecological knowledge in the context of Prosopis Juliflora invasion in Gujarat, India	India
361	An Institutionalized Human–Animal Relationship and the Aftermath: The Reproductive Process of Horse-Bands and Husbandry in Northern Yakutia, Siberia	Siberia
162	Paisang (Quercus griffithii): A Keystone Tree Species in Sustainable Agroecosystem Management and Livelihoods in Arunachal Pradesh, India	India
349	Mapping land cover change in a reindeer herding area of the Russian Arctic using Landsat TM and ETM+ imagery and indigenous knowledge	Russia
78	Herders' ecological knowledge and carnivore predation on livestock investigations in Makgadikgadi and Nxai Read online: Scan this QR code with your smart phone or mobile device to read online. national parks, Botswana	Botswana
358	Linking Local Perceptions of Elephants and Conservation: Samburu Pastoralists in Northern Kenya	Kenya
179	Female Camel Nomenclature among Arabia's Bedouins	Oman
75	Historical perspectives on pastoralism and land tenure transformation in Ngamiland, Botswana: What are the policy and institutional lessons	Botswana
22	Ethnobotanical knowledge among the semi-pastoral Gujjar tribe in the high altitude (Adhwari's) of Churah subdivision, district Chamba, Western Himalaya	India
231	Predicting the distribution of cryptic species: the case of the spur-thighed tortoise in Andalusia (southern Iberian Peninsula)	Spain
`196	The importance of being reliable e Local ecological knowledge and management of forage plants in a dryland pastoral system (Morocco)	Morocco
326	Comparison of production systems and selection criteria of Ankole cattle by breeders in Burundi, Rwanda, Tanzania and Uganda	Burundi; Rwanda; Tanzania; Uganda
218	Uses and management of Ximenia americana, Olacaceae in semi-arid east Shewa, Ethiopia	Ethiopia
88	Factors influencing local ecological knowledge of forage resources: Ethnobotanical evidence from West Africa's savannas	Ghana; Burkina Faso
72	Wolf and Bear Depredation on Livestock in Northern Sweden 1827–2014: Combining History, Ecology and Interviews	Sweden
125	Coping with difficult weather and snow conditions: Reindeer herders' views on climate change impacts and coping strategies	Finland

186	The social nature of environmental knowledge among the nomadic Woɗaaɓe of Niger	Niger
70	"I See the Grass Through the Mouths of My Animals" – Folk Indicators of Pasture Plants Used by Traditional Steppe Herders	Hungary
378	Gender, indigenous knowledge, and pastoral resource use in Morocco	Morocco
352	Traditional cattle-husbandry systems in Eritrea: cattle–man relationships	Eritrea
298	Towards Endogenous Livestock Development: Borana Pastoralists' Responses to Environmental and Institutional Changes	Ethiopia
1	Ethnoveterinary remedies used in the Algerian steppe: Exploring the relationship with traditional human herbal medicine	Algeria
2	Climate change has more adverse impacts on the higher mountain communities than the lower ones: people's perception from the northern Himalayas	China
6	Songs, Settings, Sociality: Human and Ecological Well-being in Western Mongolia	Mongolia
7	Like a Lullaby: Song as Herding Tool in Rural Mongolia	Mongolia
10	Seasonal fire management by traditional cattle ranchers prevents the spread of wildfire in the Brazilian Cerrado	Brazil
12	Nomads' indigenous knowledge and their adaptation to climate changes in Semirom City in Central Iran	Iran
13	Opportunities to integrate herders' indicators into formal rangeland monitoring: an example from Mongolia	Mongolia
14	Integrating Traditional Ecological Knowledge and Remote Sensing for Monitoring Rangeland Dynamics in the Altai Mountain Region	Mongolia; Russia; China; Kazakhstan
16	Socio-ecological dimensions of Andean pastoral landscape change: bridging traditional ecological knowledge and satellite image analysis in Sajama National Park, Bolivia	Bolivia
17	Indigenous weather and climate forecasting knowledge among Afar pastoralists of north eastern Ethiopia: Role in adaptation to weather and climate variability	Ethiopia
20	Reindeer Herders Without Reindeer. The Challenges of Joint Knowledge Production on Kolguev Island in the Russian Arctic	Russia
21	Traditional and local knowledge in land use planning: insights into the use of the Akwé: Kon Guidelines in Eanodat, Finnish Sápmi	Finland
23	Local agro-pastoralists' perspectives on forage species diversity, habitat distributions, abundance trends and ecological drivers for sustainable livestock production in West Afric	Ghana; Burkina Faso
24	Indigenous knowledge practices for sustainable lifelong education in pastoralist communities of Kenya	Kenya
27	The effect of climate information in pastoralists' adaptation to climate change A case study of Rwenzori region, Western Uganda	Uganda
29	Health risk perceptions and local knowledge of water-related infectious disease exposure among Kenyan wetland communities	Kenya
30	Shepherds' local knowledge and scientific data on the scavenging ecosystem service: Insights for conservation	Spain
37	Merging Indigenous Knowledge Systems and Station Observations to Estimate the Uncertainty of Precipitation Change in Central Mongolia	Mongolia
46	Increasing the Local Relevance of Epidemiological Research: Situated Knowledge of Cattle Disease Among Basongora Pastoralists in Uganda	Uganda

51	Traditional ecological knowledge underlying herding decisions of pastoralists	Benin
52	Understanding roles and functions of cattle breeds for pastoralists in Benin	Benin
54	Integrating indigenous local knowledge and species distribution modeling to detect wildlife in Somaliland	Somalia
57	Factors Affecting Sustainable Animal Trypanosomosis Control in Parts of Kaduna State, Nigeria	Nigeria
59	The relevance of herders' local ecological knowledge on coping with livestock losses during harsh winters in western Mongolia	Mongolia
68	Integrating remote sensing and local ecological knowledge to monitor rangeland dynamics	Kyrgyzstan
69	Important knowledge gaps among pastoralists on causes and treatment of udder health problems in livestock in southern Ethiopia: results of qualitative investigation	Ethiopia
74	Medicinal and commercial uses of ostrich products in Tanzania	Tanzania
76	Botanical ethnoveterinary therapies used by agro-pastoralists of Fafan zone, Eastern Ethiopia	Ethiopia
77	Distribution and socio-ecological impacts of the invasive alien cactus Opuntia stricta in eastern Africa	Kenya
79	An ethnobotanical survey of medicinal and edible plants of Yalo Woreda in Afar regional state, Ethiopia	Ethiopia
82	Basotho herders learn through culture and social interaction	Lesotho
83	From Herders to Wage Laborers and Back Again: Engaging with Capitalism in the Atacama Puna Region of Northern Chile	Chile
89	Indigenous Control Methods for Parasites among Pastoralists Communities in Adamawa State, Nigeria	Nigeria
96	The future of pastoralism/L'avenir du pastoralisme/El futuro del pastoreo	NA
98	Tibetan Buddhism, Wetland Transformation, and Environmentalism in Tibetan Pastoral Areas of Western China	China
103	Indigenous ecological knowledge as the basis for adaptive environmental management: Evidence from pastoralist communities in the Horn of Africa	Ethiopia
106	Tracing innovation pathways in the management of natural and social capital on Laikipia Maasai Group Ranches, Kenya	Kenya
112	Indigenous knowledge of pastoralists on respiratory diseases ofcamels in northern Kenya	Kenya
116	Transhumant Pastoralism in the Context of Socioeconomic and Climate Change in the Mountains of Nepal	Nepal
117	Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa	Ethiopia; Kenya
118	Herding conditions related to infectious keratoconjunctivitis in semi-domesticated reindeer: a questionnaire-based survey among reindeer herders	Sweden; Norway
120	Broad-scale assumptions on available pasture resources and reindeer's habitat preferences shown to be decoupled from ecological reality of Arctic-alpine landscapes	Norway
121	Are trees of intermediate densitymore facilitative? Canopy effects of four East African legume trees	Ethiopia
122	Sharing local ecological knowledge as a human adaptation strategy to arid environments: Evidence from an ethnobotany survey in Morocco	Morocco
126	Resilience of small-scale societies: a view from drylands	NA
127	Strengths and weaknesses of traditional feeding management of dairy goat farms in mountain areas	Spain
128	Terra Nullius: Colonial Violence in Prynne's Acrylic Tips	Australia
134	Pastoral livelihoods under pressure: Ecological, political and socioeconomic transitions in Afar	Ethiopia

	(Ethiopia)	
135	Morels of Palas Valley, Pakistan: A Potential Source for Generating Income and Improving Livelihoods of Mountain Communities	Pakistan
137	An ethnobotany of the Lukomir Highlanders of Bosnia & Herzegovina	Bosnia and Herzegovina
139	Wood-pastures of Europe: Geographic coverage, social–ecological values, conservation management, and policy implications	Europe
142	Loss of traditional knowledge aggravates wolf–human conflict in Georgia (Caucasus) in the wake of socio-economic change	Georgia
144	Persistence of Two Small Antelope Species in the Degraded Mutara Rangelands (Akagera Ecosystem) Based on Pastoralists' and Farmers' Perceptions	Rwanda; Tanzania; Uganda
153	Sámi reindeer herders' perspective on herbivory of subarctic mountain birch forests by geometrid moths and reindeer: a case study from northernmost Finland	Finland
154	Climate Change and Rural Livelihoods -adaptation and vulnerability in Rajasthan	Pakistan
157	A study of medicinal plants used as ethnoveterinary: harnessing potential phytotherapy in Bheri, District Muzaffarabad (Pakistan)	Pakistan
158	Trees dynamics (1955-2012) and their uses in the Senegal's Ferlo region: insights from a historical vegetation database, local knowledge and field inventories	Senegal
168	Traditional knowledge of wild food plants in a few Tibetan communities	India; China; Nepal
171	Relationship Between Pastoralists' Evaluation of Rangeland State and Vegetation Threshold Changes in Mongolian Rangelands	Mongolia
173	Herding strategies during a drought vary at multiple scales in Mongolian rangeland	Mongolia
174	Livelihood Diversification as an Adaptation Approach to Change in the Pastoral Hindu-Kush Himalayan Region	Afghanistan; Bhutan; China; India; Nepal; Pakistan
189	Ethnoveterinary knowledge of Raikas of Marwar for nomadic pastoralism	India
192	Working Knowledge: characterising collective indigenous, scientific, and local knowledge about the ecology, hydrology and geomorphology of Oriners Station, Cape York Peninsula, Australia	Australia
194	Adaptation of herders to droughts and privatization of rangeland-use rights in the arid Alxa Left Banner of Inner Mongolia	China
195	Herders' Perceptions of and Responses to Climate Change in Northern Pakistan	Pakistan
197	Traditional vegetation knowledge of the Hortobágy salt steppe (Hungary): a neglected source of information for vegetation science and conservation	Hungary
198	Sustainable Rangeland Management: Pastoralists' attitudes toward integrated programs in Iran	Iran
200	The role of drought among agro-pastoral communities in a semi-arid environment: The case of Botswana	Botswana
203	Ethnobotanical study of plants used in management of livestock health problems by Afar people of Ada'ar District, Afar Regional State, Ethiopia	Ethiopia
206	Pastoralists' knowledge of plant palatability and grazing indicators in an arid region of South Australia	Australia
207	Ethno-veterinary practices amongst livestock farmers in Ngamiland District, Botswana	Botswana

208	Envisioning the future of transhumant pastoralism through participatory scenario planning: a case study in Spain	Spain
211	The Role of Indigenous Ecological Knowledge in Managing Rangelands Sustainably in Northern Iran	Iran
213	Pastoralists' perceptions of biodiversity and land management strategies in the arid Stony Plains region of South Australia: Implications for policy makers	Australia
215	Traditional coping mechanisms for climate change of pastoralists in South Omo, Ethiopia	Ethiopia
216	Climate Change Adaptation Among Tibetan Pastoralists: Challenges in Enhancing Local Adaptation Through Policy Support	China
219	Pasture use and management strategies in the Ankole pastoral system in Uganda	Uganda
221	Ethnoknowledge of Bukusu community on livestock tick prevention and control in Bungoma district, western Kenya	Kenya
224	Febrile illness experience among Nigerian nomads	Nigeria
225	"I'd Be Foolish to Tell You They Were Caribou": Local Knowledge of Historical Interactions between Reindeer and Caribou in Barrow, Alaska.	United States
236	Challenges of assessing the sustainability of (agro)-pastoral systems	Kenya; Niger
237	Sámi traditional ecological knowledge as a guide to science: snow, ice and reindeer pasture facing climate change	Sweden
239	Resonance Strategies of Sámi Reindeer Herders in Northernmost Finland during Climatically Extreme Years	Finland
241	Seasonal precipitation forecasts: Agro-ecological knowledge among rural Kalahari communities	Botswana
245	Impacts of Arctic Climate and Land Use Changes on Reindeer Pastoralism: Indigenous Knowledge and Remote Sensing	NA
247	Gums and resins: The potential for supporting sustainable adaptation in Kenya's drylands	Kenya
248	Landscape change in the lower Omo valley, southwestern Ethiopia: burning patterns and woody encroachment in the savanna	Ethiopia
249	Doing is Learning: Analysis of an Unsuccessful Attempt to Adapt TEK/ IK Methodology to Norwegian Sa´mi Circumstances	Norway
250	Cultural dimension of wolves in the Iberian Peninsula: implications of ethnozoology in conservation biology	Portugal; Spain
264	Combining facilitated dialogue and spatial data analysis to compile landscape history	Australia
269	Traditional Ecological Knowledge Informing Resource Management: Saxoul Conservation in Inner Mongolia, China	China
270	Traditional rangeland resource utilisation practices and pastoralists' perceptions on land degradation in south-east Ethiopia	Ethiopia
275	Of forest, snow and lichen: Sami reindeer herders' knowledge of winter pastures in northern Sweden	Sweden
276	Indigenous yak and yak-cattle crossbreed management in high altitude areas of northern Nepal: A case study from Rasuwa district	Nepal
279	Partnering with local communities to identify conservation priorities for endangered Grevy's zebra	Kenya
287	Traditional fire management: historical fire regimes and land use change in pastoral East Africa	Tanzania
291	Botanical Knowledge and its Differentiation by Age, Gender and Ethnicity in Southwestern Niger	Niger
293	Participatory investigation of Contagious Caprine Pleuropneumonia (CCPP) in goats in the Hammer and Benna-Tsemay districts of southern Ethiopia	Ethiopia

297	Lifestyle and herding practices of Bahima pastoralists in Uganda	Uganda
299	Participatory indicator development: what can ecologists and local communities learn from each other?	Botswana
306	Framework for participatory assessments and implementation of global environmental conventions at the community level	Tanzania
307	Tūhoe Tuawhenua mātauranga of kererū (Hemiphaga novaseelandiae novaseelandiae) in Te Urewera	New Zealand
309	Changing communal land tenure in an East African pastoral system: Institutions and Socio-Economic transformations among the Pokot of NW Kenya	Kenya
311	Environmental perceptions and practices of livestock keepers on the Namaqualand Commons challenge conventional rangeland management	South Africa
313	Eliciting indigenous knowledge on tree fodder among Maasai pastoralists via a multi-method sequencing approach	Kenya
316	Saami reindeer pastoralism under climate change: Applying a generalized framework for vulnerability studies to a sub-arctic social–ecological system	Norway
317	Integrating local and scientific knowledge for adaptation to land degradation: Kalahari rangeland management options	Botswana
319	Ecological implications of traditional livestock husbandry and associated land use practices: A case study from the trans-Himalaya, India	India
320	Changing grazing systems in central north Namibia	Namibia
321	Herders' Perceptions on Ruminant Livestock Breeds and Breeding Management in Southwestern Niger	Niger
327	Genetic defects or generative prototypes? Competing models for livestock improvement in southern Bolivia	Bolivia
328	Herder knowledge of landscape assessments in arid rangelands in northern Tanzania	Tanzania
334	Indigenous knowledge and the desertification debate: problematising expert knowledge in North Africa	Morocco
335	Carved trees in grazed forests in boreal Sweden—analysis of remaining trees, interpretation of past land-use and implications for conservation	Sweden
336	Effects of anthropogenic fire history on savanna vegetation in northeastern Namibia	Namibia
339	Influence of selective tree cutting, livestock and prescribed fire on herbaceous biomass in the savannah woodlands of Burkina Faso, West Africa	Burkina Faso
342	The role of participatory problem analysis in performance improvement and sustainable management of rainwater harvesting (RWH) systems: A case study of Makanya village,Tanzania	Tanzania
345	Community Based Interventions as a Strategy to Combat Desertification in the Arid and Semi-Arid Rangelands of Kajiado District, Kenya	Kenya
346	Natural remedies and nutraceuticals used in ethnoveterinary practices in inland southern Italy	Italy
347	Use of indigenous ecological knowledge of the Maasai pastoralists for assessing rangeland biodiversity in Tanzania	Tanzania
348	Conflict Resolution by Participatory Management: Remote Sensing and GIS as Tools for Communicating Land-use Needs for Reindeer Herding in Northern Sweden	Sweden
350	Beyond Ground Truth: GIS and the Environmental Knowledge of Herders, Professional Foresters, and Other Traditional Communities	India
353	Current range condition in southern Ethiopia in relation to traditional management strategies: The perceptions of Borana pastoralists	Ethiopia

357	Tracking Pastoralist Migration: Lessons from the Ethiopian Somali National Regional State	Ethiopia
359	The use of herders' accounts to map livestock activities across agropastoral landscapes in Semi-Arid Africa	Niger
360	Participatory selection process for indicators of rangeland condition in the Kalahari	Botswana
362	Using indigenous knowledge in land use investigations: a participatory study in a semi-arid mountainous region of Lebanon	Lebanon
367	Representations of Nature on the Mongolian Steppe: An Investigation of Scientific Knowledge Construction	Mongolia
371	Environmental Change and Pastoral Perceptions: Degradation and Indigenous Knowledge in Two African Pastoral Communities	Kenya; Namibia
373	Traditionallo1owledge and practices of Bhotiya pastoralists of Kumaon Himalaya:.the need for value addition	India
376	Sense or nonsense? Traditional methods of animal parasitic disease control	NA
379	Sustaining indigenous communities: Symbolic and instrumental dimensions of pastoral resource use in Shimshal, northern Pakistan	Pakistan
380	Incorporating indigenous knowledge of fodder trees into small-scale silvopastoral systems in Jamaica	Jamaica
381	Ethnoveterinary medicine in Afghanistan: an overview of indigenous animal health care among Pashtun Koochi nomads	Afghanistan
383	Evaluating the effectiveness of participatory agroforestry extension programmes in a pastoral system, based on existing traditional values	Kenya

Table A1.2. Data elicited from 152 fully reviewed papers (Title, affiliation, abstract, keywords, intro, M&M, result and discussion, conclusion). Abbreviations: Pastoral_type) 1: Nomad and semi-nomad, 2: Transhumant and semi-transhumant; 3: Sedentary; 4: Trabshumant and sedentary; 5: Nomad, Semi-nomad, Sedentary; 6: Nomad, Transhumant, Sedentary: 7: Not reported. TEK_Trans) if transition was mentioned 1; if transition was not mentioned: 0. Trans_Types) Erosion: 0; Hybrid: 1; Adaptation: 2; Retention: 3.

Random_nu	Year	Pastoral_type	Ethnozology	Ethnobiology	Ethnomedicine	Ethnobotany_L	Ethnobotany	Ethnoecology	Herd management	Soco-economic-polit	Ethnoveterinary	Fire knowledge	Animal Husbandary	Ethnograpgy	Ethnoclimatology	TEK_Trans	Trans_Type	Robustness
115	2016	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
140	2015	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	3
136	2015	4	0	0	0	1	0	1	0	0	0	0	0	0	0	0	NA	NA
92	2017	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2	1
141	2015	3	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	3
150	2015	1	0	0	1	1	0	1	0	1	1	0	0	0	0	1	0	1
220	2012	2	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1
105	2016	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1
159	2015	2	0	0	1	1	0	1	1	1	1	0	0	0	0	1	0	2
31	2018	3	0	1	1	0	1	0	0	0	0	0	0	0	0	0	NA	NA
101	2016	2	0	0	1	0	1	1	1	0	1	0	1	0	0	1	0	2
233	2011	2	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
58	2018	1	0	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1
366	2000	1	0	0	0	1	0	1	1	0	0	0	0	0	0	1	0	3
315	2007	5	0	0	1	0	1	1	0	0	0	0	0	0	0	1	3	1
282	2009	2	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1
261	2010	3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3
212	2013	2	0	0	0	0	1	1	1	0	1	0	1	1	0	1	0	1
184	2014	6	0	1	1	0	1	1	1	0	0	0	0	0	0	1	0	1
182	2014	3	0	0	0	0	1	1	1	0	1	0	0	0	0	1	0	3

169	2014	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	3
281	2009	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
133	2016	1	0	0	0	0	1	1	0	1	1	0	1	0	0	0	NA	NA
283	2009	7	0	0	0	1	1	1	0	0	0	0	1	0	0	0	NA	NA
227	2012	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	NA	NA
183	2014	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	NA	NA
303	2008	7	0	0	0	0	0	1	0	0	0	0	0	1	0	0	NA	NA
310	2007	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	NA	NA
11	2019	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	3
235	2011	7	0	0	0	1	0	1	0	0	0	0	0	0	0	0	NA	NA
228	2012	7	0	0	0	0	0	1	0	0	0	1	0	0	0	0	NA	NA
	2000	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	NA	NA
62	2018	3	0	0	0	1	0	1	1	0	0	0	0	0	0	0	NA	NA
148	2015	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1
294	2008	7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	NA	NA
165	2015	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	NA	NA
259	2010	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	NA	NA
4	2019	7	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	3
292	2008	7	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	2
363	2001	3	0	0	0	1	0	1	1	0	0	0	0	0	0	0	NA	NA
289	2009	7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
175	2014	7	0	0	0	0	0	1	0	0	0	0	0	0	1	0	NA	NA
36	2018	3	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	3
180	2014	7	1	1	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
325	2006	7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	NA	NA
286	2009	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	NA	NA
48	2018	7	0	0	0	0	0	1	0	0	0	0	0	0	1	0	NA	NA
181	2014	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	NA	NA
28	2018	2	0	0	0	0	0	1	0	0	0	0	0	0	1	0	NA	NA
333	2006	3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	2

176	2014	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	2
129	2016	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	NA	NA
278	2009	4	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1
19	2019	7	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	3
301	2008	3	0	0	0	1	0	1	0	0	0	0	0	0	0	0	NA	NA
214	2012	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1
73	2017	6	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	3
229	2012	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	1
263	2010	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	NA	NA
164	2015	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	NA	NA
53	2018	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	2
280	2009	7	1	1	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
80	2017	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	NA	NA
252	2011	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
35	2018	2	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	3
91	2017	2	0	0	0	0	0	0	0	0	1	0	1	0	0	0	NA	NA
226	2012	7	0	0	0	1	1	1	0	0	0	0	0	0	0	0	NA	NA
67	2017	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3
260	2009	7	0	0	0	0	1	1	0	0	0	0	0	0	0	0	NA	NA
143	2015	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
111	2016	7	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	3
323	2007	7	0	0	0	1	0	0	1	0	0	0	1	0	0	0	NA	NA
94	2017	2	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	3
331	2006	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	NA	NA
119	2016	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	NA	NA
318	2007	7	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3
132	2016	7	0	0	0	0	1	1	0	0	0	0	0	0	0	0	NA	NA
102	2016	5	0	0	0	0	1	1	0	0	0	0	0	0	0	0	NA	NA
322	2007	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
199	2013	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	3

240	2011	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	NA	NA
87	2017	7	1	1	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
268	2010	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
97	2017	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
272	2009	5	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1
107	2016	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
130	2016	1	0	0	0	0	0	1	0	0	0	0	1	1	1	1	0	1
147	2015	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1
25	2019	7	0	0	0	0	0	1	0	0	0	1	0	0	0	0	NA	NA
114	2016	3	0	0	0	1	0	0	0	0	1	0	1	0	0	0	NA	NA
284	2009	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
300	2008	3	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	2
85	2017	7	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	3
65	2018	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	NA	NA
234	2011	7	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	3
262	2010	7	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	3
210	2013	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	NA	NA
330	2006	7	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	1
238	2011	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	NA	NA
86	2017	1	0	0	1	1	0	1	0	0	0	0	1	0	0	1	0	3
201	2013	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
47	2018	7	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3
90	2017	2	0	0	1	0	0	1	0	1	0	0	0	0	0	0	NA	NA
178	2014	7	0	0	0	0	0	1	1	0	0	0	0	0	0	0	NA	NA
209	2013	7	0	0	0	0	0	0	1	1	0	0	0	0	0	0	NA	NA
204	2013	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	NA	NA
223	2011	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	NA	NA
45	2018	2	0	0	0	0	0	0	1	1	0	1	0	1	0	1	0	3
9	2018	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	NA	NA
302	2008	7	0	0	0	1	1	0	1	0	0	0	0	0	0	0	NA	NA

146	2015	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	NA	NA
3	2019	5	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	3
277	2009	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	NA	NA
256	2010	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	NA	NA
314	2007		0	0	0	1	0	1	0	1	0	0	0	0	0	0	NA	NA
258	2010	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	3
41	2018	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	NA	NA
32	2018	1	0	0	1	0	0	0	0	1	1	0	1	0	0	0	NA	NA
34	2018	7	0	0	0	1	0	1	0	0	0	0	0	0	0	0	NA	NA
81	2017	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
177	2014	7	0	0	0	0	0	0	0	1	0	0	1	0	0	0	NA	NA
43	2018	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	NA	NA
338	2005	7	0	0	1	1	0	0	0	1	0	0	0	0	0	0	NA	NA
104	2016	7	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	3
161	2015	2	0	0	0	0	0	0	1	1	0	0	0	0	1	0	NA	NA
222	2012	7	0	0	0	0	0	0	0	1	0	0	1	0	0	0	NA	NA
63	2018	2	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	1
15	2019	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	NA	NA
44	2018	7	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2
296	2008	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	NA	NA
123	2015	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	NA	NA
71	2017	1	0	0	1	0	1	1	0	1	0	0	0	0	0	1	2	1
361	2002	7	0	0	0	0	0	0	0	1	0	0	1	0	0	0	NA	NA
162	2015	2	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	3
349	2003	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	NA	NA
78	2017	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
358	2002	7	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
179	2014	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
75	2017	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	NA	NA
22	2019	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3	1

231	2012	7	1	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA
`196	2013	1	0	0	0	1	0	0	0	0	0	0	0	0	0	NA	NA
326	2006	5	0	0	0	0	0	0	0	1	0	0	1	0	0	0	NA	NA
218	2012	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	2
88	2017	7	0	0	0	1	0	0	0	0	0	0	0	0	0	1	3	1
72	2017	2	1	0	0	0	0	0	0	1	0	0	0	0	0	1	2	1
125	2016	7	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	2
186	2014	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	NA	NA
70	2017	2	0	0	0	1	1	1	0	0	0	0	0	0	0	0	NA	NA
378	1996	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	NA	NA
352	2003	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	NA	NA
298	2008	3	0	0	0	0	0	0	1	1	0	0	0	0	0	0	NA	NA

Comparing initial (102 papers) and total (152 papers) datasets to find out if the number of the subsamples should increase or not. Wilcoxon test was used to compare two groups regarding TEK transition variable as following:

Table A1.3. Mean ranks and comparison between initial and final dataset

Dataset	N	Mean Rank	Sig
Initial dataset	102	131.76	0.378
Total dataset	152	124.64	

CodeA1.1. Script code in R

```
############## Statistical analysis for review paper
############## "global transition of pastoral traditional
############## ecological knowledge"


############## Countries of study
##############

install.packages(c("RgoogleMaps", "ggmap", "mapproj", "sf",
                   "dplyr", "OpenStreetMap", "devtools"))

install.packages("rworldmap")
library(rworldmap)

worldmap <- getMap(resolution = "coarse")

plot(worldmap, col = "white",
     fill = T, border = "black",
     xlim = c(-180, 180), ylim = c(-90, 90),
     bg = "aliceblue",
     asp = 1, wrap=c(-180,180))



countriesvisited <- data.frame(country = c("AFG", "DZA","ARG","AUS","BEN","BWA",
                                           "BFA","BDI","CAN","CHL","CHN","HRV","CYP",
                                           "EGY","GBR","ERI","ETH","FIN","GHA","HUN",
                                           "IND","IRN","ITA","KEN","LSO","MRT","MNG",
                                           "MAR","MOZ","NAM","NPL","NZL","NER","NOR",
                                           "OMN","PAK","ROU","RUS","RWA","SEN","SVK",
                                           "ZAF","ESP","SDN","SWE","TJK","TZA","UGA",
                                           "UKR","BTN","BOL","BIH","BRA","GEO","JAM",
                                           "KAZ","KGZ","LBN","NGA","PRT","SOM","USA"),
                               visited = c(3,3,2,9,3,10,6,1,2,2,18,1,1,3,1,1,33,5,3,4,19,
                                           5,2,31,3,2,13,8,2,5,8,2,5,5,1,9,1,10,2,3,1,4,11,
                                           4,9,1,13,11,1,1,2,1,1,1,1,1,1,3,1,1,1))


visitedMap <- joinCountryData2Map(countriesvisited,
                                  joinCode = "ISO3",
                                  nameJoinColumn = "country")
```

```r
mapParams <- mapCountryData(visitedMap,
                            nameColumnToPlot="visited",
                            oceanCol = "white",
                            catMethod = "categorical",
                            missingCountryCol =NA ,
                            colourPalette = c("gray95","gray90","gray85","gray78",
                                              "gray71","gray64","gray57","gray50",
                                              "gray43","gray36","gray29","gray22",
                                              "gray15","gray8","gray1"),
                            addLegend = F,
                            mapTitle = "",
                            border = "black")



do.call(addMapLegendBoxes, c(mapParams,
                             x = 'bottom',
                             horiz = TRUE,
                             bg = "transparent",
                             bty = "n"))


############## Frequenct of domains

ggplot(Year_Domains_TEKStatus, aes(x=Domain))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Domains")


############## Frequenct of domains VS TEK status (relatively)

Year_Domains_TEKStatus$TEK_Status <- factor(Year_Domains_TEKStatus$TEK_Status,
                                            levels = c("No_report","Adaptive",
                                                       "Hybrid","Constant",
                                                       "Erosion"))

ggplot(Year_Domains_TEKStatus, aes(x=Domain, y=,fill=TEK_Status))+
  theme_bw()+
  geom_bar(position = 'fill',
           width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Domains")


############## Frequenct of domains VS TEK status (Aboslute frequency)


ggplot(Year_Domains_TEKStatus, aes(x=Domain, y=,fill=TEK_Status))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Domains")


############## Frequenct of domains VS Year (violin graph)
```

```r
ggplot(Year_Domains_TEKStatus, aes(x=Domain, y=Year))+
  theme_bw()+
  geom_violin()


############## Frequenct of domains VS Year (violin graph)


ggplot(Year_Domains_TEKStatus, aes(x=TEK_Status, y=Year))+
  theme_bw()+
  geom_violin()


############## Frequenct of TEK transmision and robustness

TEK_Type_1 <- TEK_Frequencies[,3]


ggplot(TEK_Frequencies, aes(x=TEK_Trans, fill=Trans_Type))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="TEK transition")



ggplot(Robustness, aes(x=Robust))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Ethics and credits")


############## Frequenct of TEK transmision and robustness


ggplot(Moral_VS_Year, aes(x=Moral, y=Year))+
  theme_bw()+
  geom_violin()


ggplot(Moral_YES_NO, aes(x=Criteria, fill=Status))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Criterion")



##############
############## Frequenct of TEK transition VS pastoral types


ggplot(Pastoral_TEK, aes(x=Type, y=Measure,fill=Pastoral))+
  theme_bw()+
  geom_bar(stat = 'identity', position = 'dodge',
           width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="TEK type")
```

```r
Pastoral_TEK$Pastoral <- factor(Pastoral_TEK$Pastoral,
                                levels = c
                                ("Nomad","Transhumant","Sedentary"))


ggplot(Pastoral_TEK, aes(x=as.factor(Pastoral), y=Measure,fill=Type))+
  theme_bw()+
  geom_bar(stat = 'identity', position = 'dodge',
           width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="TEK type")



Satisfaction_New$Education <- factor(Satisfaction_New$Education,
                                     levels = c
                                     ("Under Diplome","Diplome","Bachelor","Msc or Higher"))

PublicationYEAR_VS_TEK$Trans_Type <- factor(PublicationYEAR_VS_TEK$Trans_Type,
                                            levels = c("No report","Adaptive",
                                                       "Hybrid","Constant",
                                                       "Erosion"))

ggplot(PublicationYEAR_VS_TEK, aes(x=Year, fill=Trans_Type))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Year")


###############
############### TEK transition VS Nomadism (Piechart)


install.packages("tidyverse")
library(tidyverse)

install.packages("plotly")
library(plotly)

install.packages("IRdisplay")
library(IRdisplay)

colors <- c("#0033FF","#33FF00","#FF0000","#FFCC00")

donut <- ggplot(data = Data_Pastoralists, aes(x=2, y = Percentage_T, fill = color))+
  geom_col(color = "black") +
  coord_polar("y", start = 0) +
  geom_text(aes(label = paste0(round(Percentage_T*100), "%")),
            position = position_stack(vjust = 0.5)) +
  theme(panel.background = element_blank(),
        axis.line = element_blank(),
        axis.text = element_blank(),
        axis.ticks = element_blank(),
        axis.title = element_blank(),
        plot.title = element_text(hjust = 0.5, size = 30)) +
```

```
  scale_fill_manual(values = colors) +
  xlim(0.6, 3.5)

donut


############## TEK transition VS Transhumance (Piechart)

colors <- c("#0033FF","#FF0000","#FFCC00")

donut <- ggplot(data = Transhumance_Data, aes(x=2, y = Percentage_T, fill = color))+
  geom_col(color = "black") +
  coord_polar("y", start = 0) +
  geom_text(aes(label = paste0(round(Percentage_T*100), "%")),
            position = position_stack(vjust = 0.5)) +
  theme(panel.background = element_blank(),
        axis.line = element_blank(),
        axis.text = element_blank(),
        axis.ticks = element_blank(),
        axis.title = element_blank(),
        plot.title = element_text(hjust = 0.5, size = 30)) +
  scale_fill_manual(values = colors) +
  xlim(0.6, 3.5)

donut

############## TEK transition VS Sedentary (Piechart)

colors <- c("#33FF00","#FF0000","#FFCC00")

donut <- ggplot(data = Sedentary_Data, aes(x=2, y = Percentage_S, fill = color))+
  geom_col(color = "black") +
  coord_polar("y", start = 0) +
  geom_text(aes(label = paste0(round(Percentage_S*100), "%")),
            position = position_stack(vjust = 0.5)) +
  theme(panel.background = element_blank(),
        axis.line = element_blank(),
        axis.text = element_blank(),
        axis.ticks = element_blank(),
        axis.title = element_blank(),
        plot.title = element_text(hjust = 0.5, size = 30)) +
  scale_fill_manual(values = colors) +
  xlim(0.6, 3.5)

donut









############## Frequenct of domains
Domain_TEK_Status$Domain_AB <- factor(Domain_TEK_Status$Domain_AB,
```

```
                                        levels = c("Herd management","Plant",
                                                   "Biology_Ecology","Climate",
                                                   "Sociocultural"))


ggplot(Domain_TEK_Status, aes(x=Domain_AB))+
  theme_bw()+
  geom_bar(width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Domains")


############## Frequenct of domains VS TEK status (relatively)

Domain_TEK_Status$Domain_AB <- factor(Domain_TEK_Status$Domain_AB,
                                      levels = c("Herd management","Plant",
                                                 "Biology_Ecology","Climate",
                                                 "Sociocultural"))

Domain_TEK_Status$TEK_Status_AB <- factor(Domain_TEK_Status$TEK_Status_AB,
                                          levels = c("No_report","Adaptive",
                                                     "Hybrid","Constant",
                                                     "Erosion"))

ggplot(Domain_TEK_Status, aes(x=Domain_AB, y=,fill=TEK_Status_AB))+
  theme_bw()+
  geom_bar(position = 'fill',
           width = 0.8,color="black",size=0.5,alpha=0.7)+
  labs(y="Frequency",x="Domains")
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